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Pillar Burst Assessment Based on Large-Scale Numerical Modeling

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Abstract

Stress concentration is a direct result of stress redistribution around an excavation, that may lead to rock bursting under specific geomechanical conditions. This paper presents a case-study of a rockburst that took place in the shaft station area of the Provence coal mine in Southern France. The mined coal seam has a 2.5 m thickness and a 10° dip angle. The rockburst occurred in 1993 at the shaft station level, where it is surrounded by several longwall panels that were excavated between 1984 and 1994. The area of the shaft station is at 1000 m depth. A very thin layer of stiff limestone occupied the middle of the exploited coal seam. A large-scale finite difference numerical model of the mine has been constructed by using FLAC^{3D}. The model simulates the area of the shaft with its irregular pillars and the longwall panels excavated between 1984 and 1993. The excavations were performed in two steps. Firstly, the galleries of the shaft station area were excavated in order to determine their effect on the failed pillar. Then, the longwall panels were excavated year by year to detect the stress and strain energy increments induced on the pillars. The origin of the rockburst was analysed based on different rockburst criteria. The results show that the vertical stress increased in the shaft station pillars due to excavation of longwall panels. In addition, we found that the small pillars have higher burst tendency than the large ones. Finally, the Burst Potential Index (*BPI*) was found to be able to estimate the pillar burst tendency based on the energy storage rate (*ESR*), however, this criterion (*BPI*) is based on calculating the stress and the energy changes in the vertical direction only.

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Keywords: Rockburst; Stress redistribution; Room-and-pillar; Longwall panels; Numerical modeling; Stored strain energy

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1. Introduction

The most probable underground instability during room-and-pillar mining is the pillar failure. Two major types of pillar failure; i) structurally controlled failure; and ii) progressive failure. Structurally controlled failure happens when a rockmass contains planes of failure (i.e. discontinuities) and the pillars are oriented unfavorably with respect to those planes of failure. This type of failure could be easily observed. Progressive failure happens where the pillar skin has little horizontal confinement and high vertical stresses. Initially the pillar remains intact and retains its bearing capacity, then, as the spalling takes place, the stresses redistribute and reach up to the pillar core progressively until it reaches a critical cross-section area and it fails. This failure could occur in a violent brittle manner which is called pillar burst, which is a type of rockburst. In order to assess pillar failure tendency, the Factor of Safety (F.S = pillar strength/average pillar stress) is used to assess pillars stability. Many authors tried to develop empirical formulas of coal pillar strength. For example, Salamon and Munro [1] studied 125 pillars in the South African coal fields, Eq. (1) is developed to assess the coal pillar strength.

$$\sigma_{ps} = K\left(\frac{w^b}{h^a}\right) \tag{1}$$

where K is the strength of a unit cube of coal, σ_{ps} is the pillar strength in (MPa), w is the pillar width, h is the pillar height and a and b are empirical constants. Salamon and Munro [1] determined values 0.66 and 0.46 for a and b constants respectively and K was determined to be equal to 7.2 MPa.

However, The Factor of Safety was found to be insufficient to express coal pillars instability in case of mines with complex geometry where pillars are irregular in shape and volume. For that, recently, the rockburst criteria are used to express pillars instability in deep underground mines. Many authors developed rockburst criteria to predict the rockburst tendency in underground mines.

1.1. Brittleness coefficient (B)

Qiao and Tian [2] carried out an experimental study to estimate rockburst tendency by using the brittleness coefficient (B), which is independent of in-situ stress field. The B coefficient is equal to the ratio between uniaxial compressive strength (σ_c) and tensile strength (σ_t) as shown in Eq.(2) The brittleness coefficient has been reported by Peng and Wang [3] and Cai et al. [4] as well.

$$B = \frac{\sigma_c}{\sigma_t} \tag{2}$$

The rockburst tendency has been classified according to the B value as:

I. No rockburst: $B > 40$.
II. Weak rockburst: $26.7 < B \leq 40$.
III. Moderate rockburst: $14.5 \leq B \leq 26.7$.
IV. Strong rockburst: $B < 14.5$.